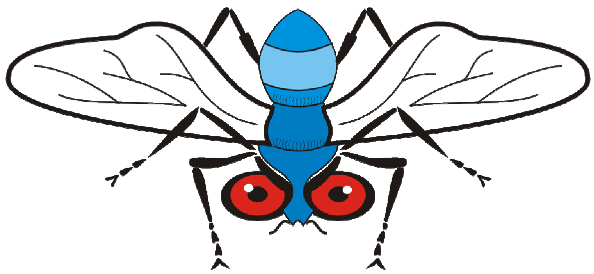


The RoboBall™ FlyEye Sensor has been designed to be used with pre-programmed robots competing in the 'RoboCup Junior' * competitions.

The **RoboBall™ FlyEye Sensor** was born out of practical experience with the most common and frustrating problem encountered in constructing a soccer robot - reliably finding the ball!

Features of the **RoboBall™ FlyEye Sensor**:

- Designed to work directly with LEGO® RCX/NXT*.
- 16 output levels, relative to the ball direction and distance from ball (intensity).

Mechanical Specifications:

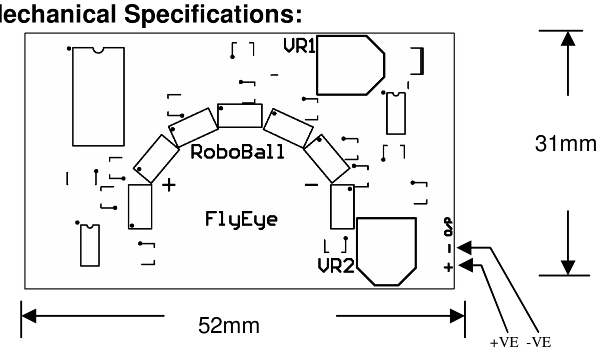


Fig.1

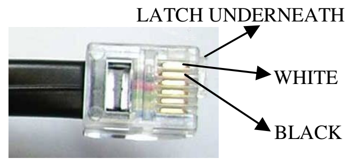
- Dimensions : ± 0.5mm
- Weight : 65g
- Powered from NXT (see section 1.2)
  RCX (see section 1.3)

1. Installation Instructions

1.1 **The RoboBall™ FlyEye Sensor** may simply be connected to your standard LEGO®MINDSTORM® RCX/NXT* interface with no modification to the **RoboBall™ FlyEye Sensor**.

Connecting to the NXT*

1.2 You will need a LEGO® NXT* extension lead. Cut the lead in half or to a desired length and then separate the White and Black wires in the NXT lead stripping the insulation on these to bare 3 - 5mm of copper. The other four wires are not required; they should be cut off carefully so the centre copper conductors can not touch together.



LEGO® NXT* lead

Slide on 15mm of 5mm heatshrink tubing over full cable, slide 10mm of 2.5mm heatshrink over both wires then 10mm of 1.5mm heatshrink tubing over the individual White and Black **RoboBall™ FlyEye** wires. Twist and solder striped Black NXT wire to the Black **RoboBall™ FlyEye** wire, then twist and solder striped White NXT wire to the White **RoboBall™ FlyEye** wire, slide the 1.5mm heatshrink over the joints and carefully heat the heatshrink to insulate the terminations, avoid heating larger heatshrink. The larger sections of heatshrink can be slid over both and carefully heated; this gives isolation and strain relief. Now the LEGO® cable can be plugged into the appropriate NXT* input.

Connecting to the RCX*

1.3 You will need a LEGO® RCX* extension lead. Cut the lead in half or to a desired length and then strip the insulation from the two black wires baring 3 - 5mm of conductor. Slide 10mm of 2.5mm heatshrink over both wires then 10mm of 1.5mm heatshrink tubing over the individual White and Black **RoboBall™ FlyEye** wires. Twist and solder a striped Black RCX wire to the Black **RoboBall™ FlyEye** wire, then twist and solder other striped Black RCX wire to the White **RoboBall™ FlyEye** wire, slide the 1.5mm heatshrink over the joints and carefully heat the heatshrink to insulate the terminations, avoid heating larger heatshrink. The larger section of heatshrink can be slid over both and carefully heated; this gives isolation and strain relief. Now the LEGO® cable can be plugged into the appropriate RCX* input
(Section 2.0 will check correct orientation of block on RCX* for polarity purposes)

1.4 The photodiode detectors are mounted on the underside of the PCB for a reason; the overhang of the PCB helps shield them from the effects of intense overhead lights that could confuse the **RoboBall™ FlyEye**. So make sure you have it the right way up! Mount the **RoboBall™ FlyEye's** PCB horizontally at about the mid height of the **RoboBall™.** There is some advantage to mounting the **RoboBall™ FlyEye** higher and tilting it down a little as this can reduce the sensitivity to light sources outside the soccer field. The vertical field of view extends 20° above the plane of the PCB (at 50% sensitivity) which means a bright infra-red light source low in the background can be detected - sunlight coming through distant windows is a particular problem. Fluorescent lighting contains little infra-red light and will have less effect than incandescent lights or sunlight. If you are careful, you might choose to bend all the photodiodes away from

the PCB slightly as an alternative to tilting the PCB. The 4 holes in the PCB (see Fig.2) can be used to assist with mounting the **RoboBall**™ **FlyEye Sensor** to your robot, however due to slight hole size and hole to hole distance variations in the PCB manufacturing process we do not recommend that these hole be used for power connections, as they may prove to be unreliable.

1.5 The light emitted by a **RoboBall**™ can vary depending on whether one of the LEDs is facing you or not. So make sure that when you mount the **RoboBall**™ **FlyEye** that the plane of maximum sensitivity is directed towards the centre of the ball when it is close up - that gives it the best chance of catching the output from at least one of the **RoboBall**™ LEDs as the ball rotates.

1.6 The **RoboBall**™ **FlyEye Sensor** should now be ready to use.

2. NXT* Software/Firmware Compatibility

The new NXT allows for compatibility with the old RCX sensors; however you will need to download the appropriate software.

2.1 If you are using NXT* you will need to update the software programs running in your NXT*, go to the website http://mindstorms.lego.com/Support/Updates/. There you will find a number of programs; you will need to load your NXT with “LEGO MINDSTORMS NXT Firmware v1.04”, “Dynamic Block Update” and “Legacy Block Library”.

2.2 If you are using a RCX you will then need to write a small RCX* program to configure one of the input ports as a powered sensor and then change the sensor to ‘raw’ mode. (See the programming section if you are not sure how to do this.) Download the program and run it. Press the ‘view’ button on the RCX* to view the port you have just configured. With nothing plugged into the port, the display should read 1023, if it does not then check your program. If you plug a standard Lego* light sensor into the port then the red LED on the sensor should light up; again, if this doesn’t happen, check the port configuration before proceeding.

2.3 Now plug the **RoboBall**™ **FlyEye** into the port that you just configured and double check that the display is still ‘viewing’ that port. Unlike Lego light sensors, the **RoboBall**™ **FlyEye** will only operate correctly if it is plugged into the RCX* port the correct way round. Don’t worry; the **RoboBall**™ **FlyEye** is protected against the reverse polarity that occurs when it is plugged in the wrong way. If you see a constant number around 630 displayed then you need to reverse the connector. When you plug the **RoboBall**™ **FlyEye** in the right way round it will go through an initial power-on test which will result in a sequence of readings starting at around 925. After about 1 second, the displayed value should decrease, over a period of about 1.5 seconds, until a number around 250 is displayed for a further 1 second. If you see this sequence of numbers then your **RoboBall**™ **FlyEye** is working properly and you have connected it correctly. Don't worry if the numbers are not exactly 925 or 250 etc. there is always some slight variation between devices.

2.4 After the initial power-on test, the displayed values will start to change depending on what the **RoboBall**™ **FlyEye** sees. Remember that the **RoboBall**™ **FlyEye** goes through its self test every time it is turned on; so make sure that you have your robot turned on at least a few seconds before you need to run your soccer program!

3. Understanding how it works!

3.1. There are seven photodiodes (see Fig 3) on the underside of the **RoboBall**™ **FlyEye** and these look in different directions. A microcontroller, built into the **RoboBall**™ **FlyEye**, compares the light intensity seen by each of the seven photodiodes and picks the brightest one. The **RoboBall**™ **FlyEye** can send 16 different voltage levels to your robot. On an RCX* port in ‘raw’ mode these correspond roughly to values starting at 250 and increasing in steps of 45, i.e. 250, 295, 340, 385, 430, 475, 520, 565, 610, 655, 700, 745, 790, 835, 880 & 925. (See the 3 -wire interface section for the actual voltage levels) Note these values are approximate and will depend on the exact setting of VR1 (see the adjustments section), there will also be some variation in the values during normal operation and your program must be written to deal with this. The lowest 7 values (250 - 520) are used to indicate which photodiode is seeing the brightest light. So a value of 250 indicates the brightest light is seen by the far left photodiode, a value of 385 indicates straight ahead and a value of 520 is far right. The highest nine values (565 - 925) are used to indicate the intensity of the light seen by the brightest photodiode. See the ‘adjustments’ section for more information on the intensity values.

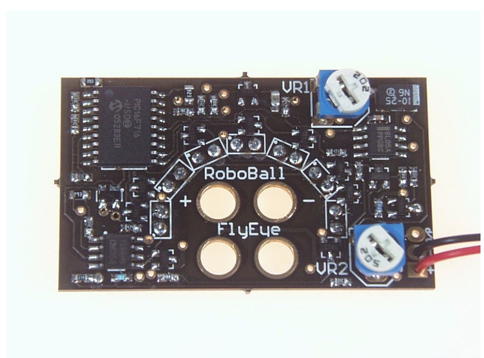


Fig 2

The **RoboBall**™ **FlyEye** switches between indicating direction and intensity about ten times per second when the light source is steady. However, if the direction to the brightest light changes then the **RoboBall**™ **FlyEye** gives priority to direction

information and will output the new direction value immediately and in preference to a new intensity value. Having said that, an intensity value will always be output at least 5 times a second. See the programming section for more information on how to use the values read from the **RoboBall™ FlyEye**.

3.2. Note that when you use the 'view' button to look at the output of the **RoboBall™ FlyEye** the RCX* refreshes the display quite slowly so that you will not see the **RoboBall™ FlyEye** values change 10 times per second. However a properly written program will have no trouble reading these rapid changes.

4. Adjustments.

4.1. There are two adjustments available on the **RoboBall™ FlyEye** set by VR1 & VR2, shown in Fig 1 & Fig 2. These are pre-set at manufacture and should not need altering but if you do.

4.2. VR1 adjusts the 'digital' output levels. To set this, locate the **RoboBall™ FlyEye** so that the far left photodiode is facing a very bright light and the output switches between the minimum and maximum values (250 and 925), realistically 275 and 900. Rotate VR1 to adjust the range.

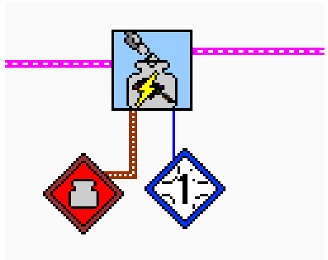
4.3. VR2 adjusts the optical scale. The **RoboBall™ FlyEye** senses light on a 'logarithmic' scale. That means that light levels corresponding to successive output values differ by the same factor. This is similar to how a human eye perceives intensity and means that the **RoboBall™ FlyEye** can indicate intensities ranging from bright sunlight to a dimly lit room on one scale. The best guide to adjusting the optical intensity covered by the scale is to put the soccer ball as close as it will get to the **RoboBall™ FlyEye** and adjust VR2 until the intensity just registers at the top of the scale, i.e. a Max. reading of about 920 (875 – 925).

5. Programming

5.1 This section is for RCX* based robots, but you can use it as a general guide for other platforms. The first step is to configure the input port to be a powered sensor (like a light sensor). The RCX* reads all sensors on a range 0 to 1023 but then applies a conversion depending on what type of sensor is being used. The conversions used for the various Lego* sensors do not make much sense for a **RoboBall™ FlyEye** so the next step is to tell the RCX* that we want the 'raw' readings. If you are using NQC and have the **RoboBall™ FlyEye** on Port 1 then the two commands to use are

```
SetSensor (SENSOR_1, SENSOR_LIGHT);
SetSensorMode (SENSOR_1,SENSOR_MODE_RAW);
```

If you are using Robolab* then use the Powered Sensor Container VI to store the **RoboBall™ FlyEye** reading in a container. In the example below, the **RoboBall™ FlyEye** would be plugged into port 1.



5.2 To simplify the logic and to round off the effects of small variations in the **RoboBall™ FlyEye** output it is a good idea to convert the raw values into something easier to interpret. The following NQC function shows one way you might do this:

```
int Direction;
int Intensity;

void Read FlyEye ()
{
   int Temp;
   Temp = (SENSOR_1 - 230)/45;
   if (Temp<7)
     Direction = Temp;
   else
     Intensity = Temp-7;
}
```

In this example, values up to 274 will be converted to Direction = 0, between 275 and 319 converts to Direction = 1 and so on. The nominal output levels of the **RoboBall™ FlyEye**, 250, 295 etc will fall in the middle of these ranges and give the best immunity to any noise on the output.

5.3 In Robolab* you can do a similar conversion using a Formula Container VI to do calculations with the number stored by the Powered Sensor Container VI.

Whether you use NQC or Robolab*, make sure that you read the **RoboBall™ FlyEye** value into a container and then use the stored value to do related calculations or branches in your program. The value read from the port can change at any time and there is no guarantee that two successive reads from the port will return the same value no matter how close together they are in your program.

Because the **RoboBall™ FlyEye** can switch its output ten or more times a second you need to arrange that your program calls the reading function (SubVI) at least 20 times a second if it is not to miss an important change in direction - the ball can move a surprising distance in a tenth of a second! You might

consider using a separate task to read the **RoboBall™ FlyEye** so that the values are always kept up to date. This simplifies the programming but be aware that the RCX* multi-tasking sometimes creates unexpected problems when your robot needs fast reactions.

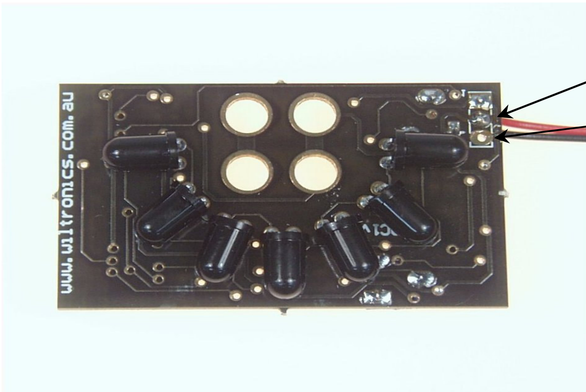


Fig. 3

6. **More testing...**

By now you probably know that the secret to good robotics is test, test and test again. So, once you have the **RoboBall™ FlyEye** plugged in and have observed the initial power on test and understood what the output values mean, perform the following simple test to demonstrate the **RoboBall™ FlyEye's** operation.

You need a single bright light (a desk lamp or torch for example) in an otherwise dimly lit room. Make sure the RCX* has run a program to set the input port correctly and cycle the RCX* display to the **RoboBall™ FlyEye** port with the view button. Turn the light on and position the **RoboBall™ FlyEye** so that the far left photodiode (looking from the top of the board) is facing the light. Watch the RCX* display; you should see it change between a number near 250 and a number higher than 600. A very bright light like a quartz halogen desk lamp should read a value near 900 at close range. Slowly rotate the **RoboBall™ FlyEye** or move the light so that each of the other photodiodes faces the light in turn. The display should alternate between the higher intensity value and a different lower value depending on which photodiode faces the light. When the bright light is straight ahead the lower value should be about 385 and when it is to the far right, about 520. Again, some variation in these values is normal and the values may be changed by the setting of VR1.

Now change the intensity, either by moving away from the light or by shading some of the light near the source, you should now see the intensity value (the higher number that is displayed) decrease.
If you're not using an RCX*, then you can view the **RoboBall™ FlyEye** output with a digital multimeter but be aware that some multimeters will not read the output correctly as it switches rapidly between the different output voltages.

7. **Other things to think about...**

You'll notice that the photodiodes are spaced closer together towards the forward direction. Arranging the photodiodes this way gives your robot the most precise information about changes in ball location where it needs it most, just like a human eye which perceives more detail in the centre of vision with only vague detail on the periphery. The field of view of the individual photodiodes is wide enough that they overlap their neighbour's field of view. So there are no 'gaps' in the **RoboBall™ FlyEye**'s vision.

The most obvious way to make use of the **RoboBall™ FlyEye** output is to have your robot turn until the ball is straight ahead and then go forward. If the ball moves to one side or the other your robot can correct its direction while still giving chase. But you can also have your robot turn until the ball is in front of one of the other photodiodes. With a slight change of programming you can have your robot hit the ball from the left or right or even circle around it. Experiment and have fun!

	RCX port ("RAW" mode)	Output Voltage
Direction1	250	1.22V
Direction 2	295	1.44V
Direction 3	340	1.66V
Direction 4	385	1.88V
Direction 5	430	2.10V
Direction 6	475	2.32V
Direction 7	520	2.54V
Intensity1	565	2.76V
Intensity 2	610	2.98V
Intensity 3	655	3.20V
Intensity 4	700	3.42V
Intensity 5	745	3.64V
Intensity 6	790	3.86V
Intensity 7	835	4.08V
Intensity 8	880	4.30V
Intensity 9	925	4.52V

Table 1.

"RoboBall™ FlyEye Sensor" Design & Specifications:

DESIGNED AND MANUFACTURED IN AUSTRALIA